Driving the Bus: A Radiology Case Study Utilizing Rich Picture Diagramming and CATWOE to Capture Staff Perceptions and Inform Service Improvement Scenarios

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Abstract: *Introduction:* Demand for computed tomography (CT) services is increasing. This empirical work in a CT setting, examines how qualitative methods were used to identify staff perceptions and opportunities for service improvement. The use of soft systems methodologies (SSM) as an action research tool in radiology is considered. *Methods:* Hospital Staff were interviewed to create a root definition of the CT service. In a diagramming session, a rich picture (RP) was created and augmented with staff input. Utilizing the RP, a session was facilitated with radiology decision makers to identify a list of culturally desirable and feasible process improvement scenarios. *Results:* Root definitions were created of the CT service from the perspective of the staff. The RP graphically illustrated the key features of the CT service and represented a shared understanding of the service. A targeted set of culturally feasible and desirable service improvement recommendations were identified. Four directly attributable implemented workflow changes were identified. *Conclusion:* RP diagramming provided an opportunity to involve staff in research while capturing their perceptions and resulted in a shared understanding as well as targeted opportunities for CT service improvement. The implemented workflow changes resulting from the SSM approach demonstrated its use as an action research tool.

1 INTRODUCTION

The challenges facing CT service provision are many. Resources are limited and the demand for Radiology and CT services is increasing year on year. (Conlon & Molloy, 2019; Granja, Almada-Lobo, Janela, Seabra, & Mendes, 2014)

The number of over 65 year olds will double between 2011 and 2031 and the increasing prevalence of diabetes and obesity among young people suggests that future elderly cohorts might suffer from a range of co-morbidities. (Lakdawalla, Bhattacharya, & Goldman, 2004; Sturm et al., 2007) (Central Statistics Office., 2015). The calculation of radiology workload is inherently reductionist in that it is based on medical requests for imaging of different body parts. (Rcsi, 2011; Reeves, 2005) (Reeves, 2005) Radiology workload assessment in terms of numbers of examinations completed is a reductionist and crude measurement (MacDonald, Cowan, Floyd, & Graham, 2013; Naylor, 1992; Ondategui-Parra et al., 2004; Pitman, Cowan, Floyd, & Munro, 2018; RCSI, 2011; Sunshine & Burkhardt, 2000). This work examines the intertwined elements of a CT service including the motivations and priorities of those involved in the service using tools from soft systems methodology (SSM) to identify opportunities for service improvement (Crowe, Brown, et al., 2017). SSM is a well-established action research approach and requires one to use the experience itself as a research object and to extract learning through conscious reflection. This process leads to action in a never ending learning cycle: once the action is taken, a new situation with new characteristics arises and the learning process starts again (Rodriguez-Ulloa & Paucar-Caceres, 2005).

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In this case study, SSM tools are used to create a shared understanding of the CT service, as part of a larger operations research (OR) project utilizing simulation modelling. Operations research (OR) is the art of applying analytical methods to the solution of complex management problems(Ackermann, 2012a). OR has the potential to improve radiology workflows and systems and can capture human responses to work pressure (Greasley & Owen, n.d.; Oliva, 2002) (Booker, O'Connell, Desai, & Duddalwar, 2016; Van Lent et al., 2012). The SSM tools used are CATWOE and rich picture (RP) diagramming. CATWOE focuses on creating a root definition of a service from varying perspectives, aiming to illicit perspectives on an issue by identifying the Customers, Actors, Transformation, Weltanschauung/Worldview, Owner and Environmental constraints (Crowe, Brown, et al., n.d.; Lamé, Jouini, Stal-Le Cardinal, & Lam, 2019). Rich picture (RP) diagramming allows groups to explore their information flows, communications, subconscious, occult sentiments and conflicted understandings(Rodriguez-Ulloa & Paucar-Caceres, 2005) (Bell, Berg, & Morse, n.d.; Berg, 2015). RP diagrams use cartoon like freeform drawings to enact or provoke knowledge and reflection and therefore allow a problem situation to be viewed in a more structured way, without commitment to any particular solution(Peter Checkland, 1985) (P Checkland, 1999). The purpose of a RP is to firstly determine what is learnt in the process of its construction and secondly to use the picture as a means of conveying a message or sharing an understanding. Crowe et al created a RP diagram from interview recordings in a mixed methods case study to analyze the service provided to infants with congenital heart disease (CHD), see figure 1(REF). In the subsection of the RP, the hospital, the various staff, patient and family are represented along with their fears and concerns and perceived issues. They concluded that RP diagramming facilitated the work in acknowledging and working with multiple perspectives systematically while considering feasible and culturally desirable targeted service improvements (Crowe, Brown, et al., 2017).

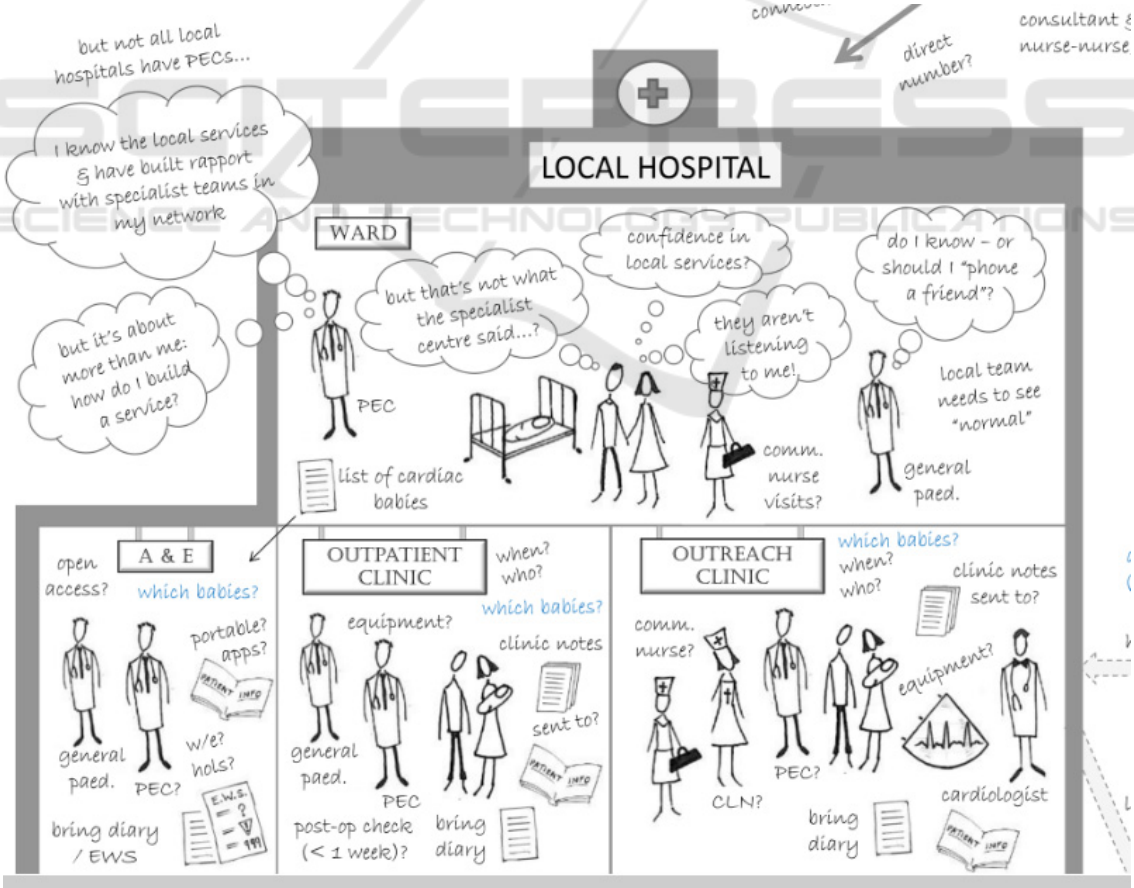

Figure 1: Subsection of RP diagram Crowe et al, 2016.

RP diagramming in healthcare has facilitated the provision services and education (Crowe et al., 2017; Goebel, Cristancho, & Driman, 2019). There is however a paucity of literature using SSM techniques to formally capture the staff experience of providing CT and other diagnostic imagining services. SSM has the potential to allow staff to share their experience of service delivery (Bate, 2000). To summaries, the research paper objectives are as follows:

1. To elicit knowledge relating to the factors affecting CT service delivery from staff and create a shared understanding of the CT service using RPs and CATWOE statements.
2. To identify potentially feasible and culturally desirable targeted service improvements for use in an OR projects using simulation modelling to address the increasing demand for CT.
3. To identify implemented workflow changes which resulted from the use of the SSM tools.
4. To produce a RP diagram for dissemination.

2 METHODS

A SSM approach was deemed appropriate given its focus on engaging multiple staff perspectives and its ability to illicit information and potential simulations (Peter Checkland, 1999). Data was collected over a one month period using semi-structured interviews and RP diagramming sessions.

The case study hospital provides a 24/7 acute surgical, medical and critical care service with emergency and maternity services and has approximately 100 inpatient beds. In radiology, a single CT scanner provides a scheduled service from 8.30am to 5pm and a 24 hour emergency service for inpatients and accident and emergency patients.

Approval to conduct the study was obtained from the hospital management team. Informed consent was sought from all participants and this consent was approved by hospital management. The researcher had ten years experience in CT and was employed for four years in the CT department prior to commencing the research work. All data was anonymized and stored in line with local data protection guidelines. Figure 2 outlines the methodological approach taken.

2.1 CATWOE

A 20 minute PowerPoint introduction was provided to staff on the use of SSM, RP diagramming and CATWOE, staff were provided with examples of RP diagrams (Crowe, Knowles, et al., n.d.). Interviews were conducted to elicit information from staff regarding the important aspects of the service by

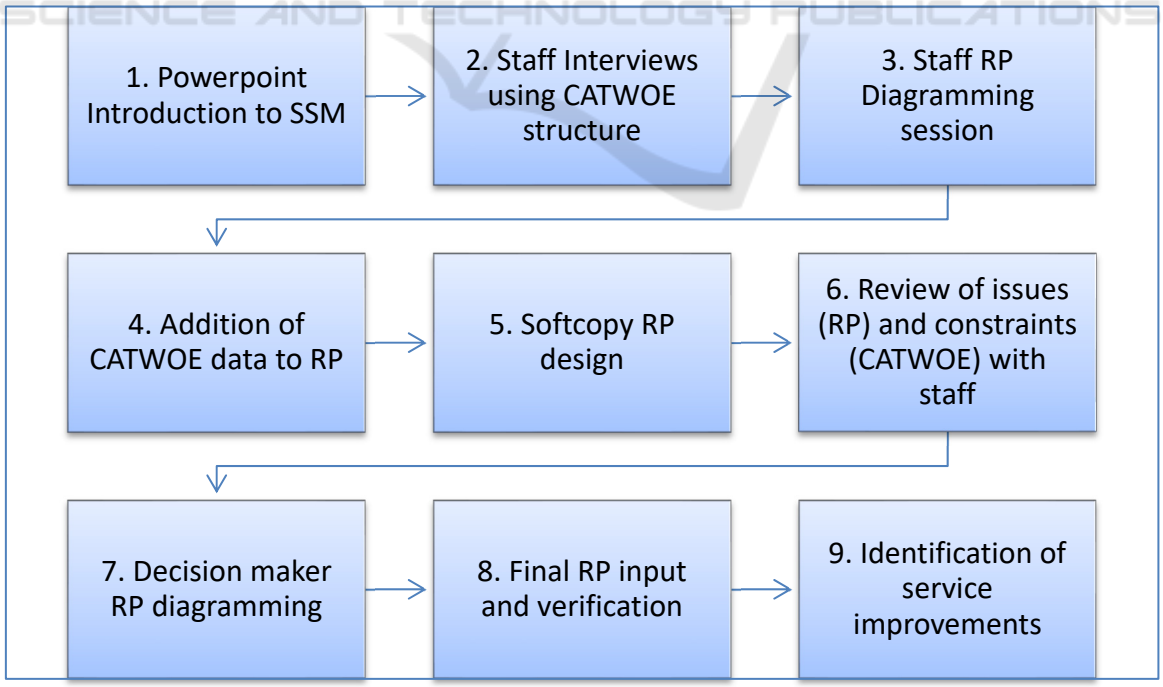

Figure 2: Process of RP building.

Table 1: CATWOE pneumonic explanation.

CATWOE	Explanation
Customers	Beneficiaries of service or transformation process (T)
Actors	Who carries out the service or transformation process
Transformation process	What occurs to inputs in the process
Worldview	The worldview - why the service or transformation process is important
Owners	Those who can stop the service or transformation process
Environment	Environmental constraints

identifying the customers, actions, transformation process, worldview, owners and environmental constraints (CATWOE) of the CT service(Crowe, Brown, et al., n.d.). Convenience sampling was used to recruit interview participants (n=5), which included a CT clinical specialist, a department manager, a hospital referrer, a porter and a nurse. Staff were interviewed individually in their place of work and the interview schedule was based on the SSM pneumonic CATWOE (Peter Checkland, 1985, 1999). Notes were taken on a pre-printed document with sections for each part of the CATWOE pneumonic (Table 1).

2.2 RP Diagramming

In step 3, the CT clinical specialist, two senior CT radiographers, department nurse and one radiologist were directly involved in the RP session. The facilitator was a member of staff from the radiology department. During a 35 minute picturing session, participants were presented with a blank page and a set of colored markers, and were asked to draw freehand graphics representing their interpretation of the service(Berg, 2015). Participants were instructed to avoid the use of text where possible(Bell et al., n.d.). Questions were encouraged throughout the session. The facilitator prompted throughout so as to uncover difficult to observe workflows and communications. Where text could not be avoided comments and speech bubbles were written directly onto the RP poster as well as a list of perceived issues generated. While not directly involved in the RP session, the worldview and environmental constraints of the porter and the nurse obtained from the structured interviews were added to the RP by the facilitator (step 4).

2.3 Creating the Soft Copy RP and Validation

In order to create a version of the RP which could be disseminated outside of the case study, drawings were created to represent the hand drawings of staff (step 5). These were scanned and imported into Microsoft Publisher for arranging. Where text was used these comments were typed and added to the softcopy version. Once completed the RP was presented to staff members. The purpose of this was to allow participants to talk through the diagram, discuss insights and to confirm and refine the RP diagram(Bell et al., n.d.; Berg, 2015). Suggested changes were made and once again shown to staff for verification.

In step 6 the list of perceived issues generated during the RP diagramming session and the constraints identified in the CATWOE statements were reviewed by the participants and scrutinized so as to identify important aspects of the service(Howick & Ackermann, 2011; Rashwan, 2017).

2.4 Targeted Set of Service Improvement Opportunities

A guided discussion with radiology decision makers (Radiology manger and Clinical Director) was arranged in which the soft copy version of the RP diagram and the original staff diagram were presented. The intention of showing both was to reassure participants of the informal nature of the drawings whilst also providing the clarity of the "cleaned up" version. Decision makers were afforded the opportunity to contribute to the RP (step 7) and asked to identify a targeted set of culturally feasible and desirable changes to the service (step 9). Decision makers were prompted to consider potential changes to the CT schedule, the number of CT scanners, the addition of staff and skill mix of staff etc (Crowe, Knowles, et al., n.d.).

3 RESULTS

3.1 RP Diagram

The softy copy final version of the RP (Figure 3) captures the key features of the CT service, such as staff activities, the process, the environment, the delays, distractions and external factors contributing to workload and affecting service delivery. A clock and phone are visible in each room to represent the time sensitive nature of the work and constant "often repetitive" communications occurring between staff. Background chatter whilst scanning is a common occurrence.

A clear definition is made between the inpatient and outpatient services by placing these groups on separate floors of the hospital. The inpatient service includes the acute medical assessment unit and accident and emergency department, whose patient's generally require an immediate service. The experience of the GP in the community is depicted and their awareness of growing waiting lists. GP and outpatient waiting lists appear as an external factor as these do not impact the daily operations of the service and were a concern at management/decision maker level. A graphic representing an inpatient depicts how patient complexity varies in terms of a patient's care needs, infectiousness, mobility and exam complexity. The outpatients are seen to be experiencing delays and the staff are conscious of the inconvenience a delay causes and feel responsible.

The frustration of the staff nurse as they seek to confirm a patient's future scan time is also depicted. They just want a verbal answer and do not want to refer to the information system; they may not remember their password or may imagine a phone call is quicker than logging on to the RIS/PACS. Bad habits have appeared over the years and they are conditioned to expect verbal confirmation of a time. They are under pressure to ensure a scan happens in a timely manner because they know discharge is dependent on it or are aware the patient is waiting a long time or is deteriorating.

External factors affecting service provision are grouped to the left of the diagram and appear outside of the drawing of the hospital. It was agreed to locate waiting lists as external as they were not a concern for CT service provision on a daily basis. Age and infection and chronic diseases and newspaper headline also appear externally.

3.2 Contributing Example

The RP diagram shown in Figure 3 represents various contributions by participants. For example, one radiographer (MD) created their own drawing using the metaphor of a bus Figure 4. The halo represents the radiographer arriving to work like an "angel". Conscious of staying ahead of demand, the radiographer arrives early to prepare the necessary blood results and information required for each patient request. This all changes by 11am however at which point their "heart is broken" and their "brow furrowed" due to the number of phone calls and interruptions.

This radiographer is also represented in the RP diagram in Figure 3 and is seen to have many items on their mind. Phone calls result where a referring doctor is looking for another phone number or where they are seeking verbal confirmation of a scan time which may already be available on the Radiology Information System (RIS). They describe being the lead radiographer in CT as like being the driver of a bus with other staff on board. If the bus goes into third gear there will be casualties – speed kills. If they stay in first or second gear everyone is smiling at the end of the day. The mantra of the radiographer is "one man, one job", while it may be possible to scan (acquire images), plan (schedule work) and run (transfer patients, test intravenous lines, inject, position patients etc), errors are an inevitably of that.

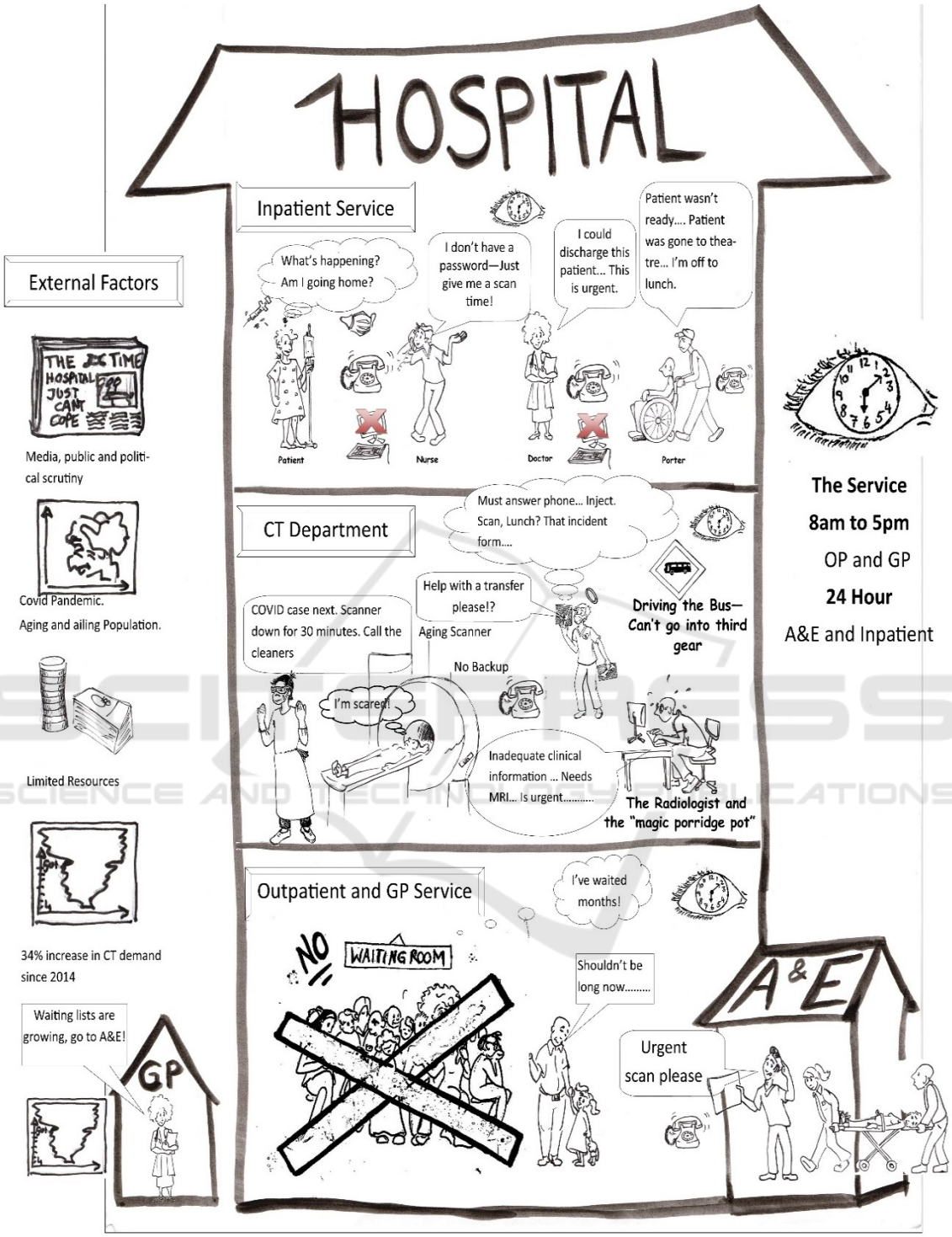

Figure 3: Soft Copy RP Diagram created by the research team and validated by participants and staff.

3.3 Perceived Issues and Constraints of the Service

Table 3 presents a sample of the total issues and constraints (n=32) identified by staff during the RP diagramming and CATWOE interviews.

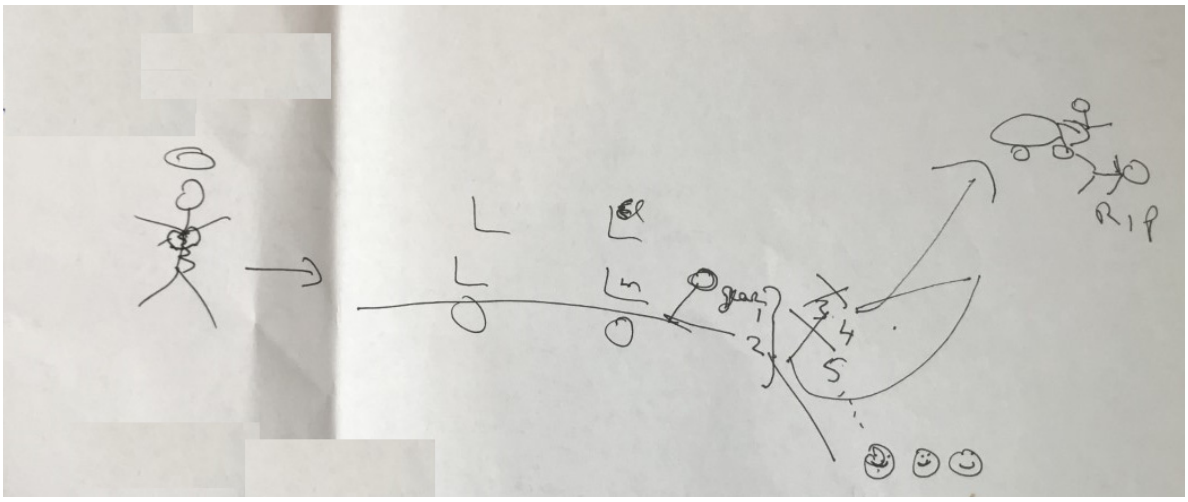

Figure 4: The Bus - A Radiographer's metaphor for the CT service.

Table 2: Sample of service issues and constraints.

Source	Perceived Issue
Clinical Specialist	Overall demand is increasing and the CT service has multiple referral sources with patients of varying priority, priority may change over time. Constant reprioritization is required. Phone calls and visits from the various referral sources cause time delays and distract radiographers who are scanning. Staff want verbal confirmation of scan times even though this information is available on the RIS.
Radiographer1	In order to have all the information I need to hand; I have to transcribe information onto a paper schedule. Some use the RIS but this works for me and saves me from going in and out of multiple screens, multiple times or relying on my memory. Delays occur when staff are not available for the manual transfer of patients from their bed/trolley to the CT scanner and back again.
Radiographer2	The skill mix amongst the radiographers and percentage of staff able to cannulate and inject patients has been depleted due to recent staffing changes. Delays result where transportation is not immediately available for inpatients, this may be due to porter or wheelchair shortages or where patients on the wards are not ready to leave the ward when the patient arrives.
Radiographer3	Quite often someone forgets to arrange transportation for the inpatients who are drinking on the wards. There can be up to 3 calls per inpatient to arrange preparation and transportation and to discuss whatever time's been allocated to them. We need a dedicated workstation for planning – there are constant demands for the PC from multiple staff which breaks concentration when planning. The Lab system and RIS/PACS systems should be side by side or on the same PC.
Porter:	At break times we may only have one porter covering several areas Patients are not always ready to be transported when we arrive on the ward and we have to ring back to CT to explain, or we think they are going to need a wheelchair but we arrive and they need a bed.
Manager:	Waiting lists are increasing and so is demand. The CT scanner is old and its tube is no longer fully covered under service contract.
Nurse	Post colonoscopy we provide a hot drink and a sandwich. We have to ring the canteen for this and the tea is often cold on arrival.

3.4 Changes as a Result of the RP

Four changes were implemented following the use of the SSM tools.

1. Clinical specialist – Issue (1)

A handover tool was designed for staff to ensure that information relating to patients requiring a scan was not lost between the day and night shift who may not see each other. Such information may include inpatients being prepped with oral contrast in advance of a scan or requiring hydration or repeated blood tests.

2. Clinical specialist – Issue (2)

Ward staff were offered RIS/PACS training and advised to consult the RIS/PACS for to check if a time had been allocated to an inpatient scan request. The practice of verbally informing ward staff of scheduled times ceased.

3. Radiographer 3 – Issue (1)

The method of arranging transportation for inpatients requiring oral contrast was changed. Previously a radiographer was responsible for arranging transportation for inpatients 10 minutes in advance of the scan so as to ensure no delay. Post research the healthcare assistants undertook to notify clerical staff of the intended scanning time and the need for transportation.

4. Nurse - Issue (1)

Post CT examinations such as CT colonoscopy and CT cardiac angiogram patients were previously provided with refreshments such as Tea and scone/sandwich. One phone call to the canteen was made per patient and delays were common. Changes were made where a daily delivery of sandwiches and juice boxes to CT was arranged and the necessity to place individual orders removed. A targeted set of potential service improvement scenarios were identified in the final step of the methodology (Table 3).

4 DISCUSSION

4.1 General Study Reflection

This paper sought to elicit knowledge from radiology staff while creating a shared understanding of the CT service using RPs and CATWOE statements and to identify potentially feasible and culturally desirable targeted service improvements. This study showed that the important aspects of a service could be represented on a RP

Table 3: Potential service improvement scenarios.

Service Improvement Scenario	Benefits
Extended CT Schedule: Changing the CT Schedule from 8.30 to 5 to 8am to 8pm.	Outpatient capacity increased, waiting lists decreased. Dedicated outpatient and GP block booking possible minimizing disruption from inpatient demand.
Addition of a permanent second CT scanner	Inpatient and outpatient cohorts will have dedicated scanners. Less infection control related downtime on outpatient scanner. Waiting lists will be decreased. The addition of more preparation and observation space.
Combined simulation: The addition of a temporary mobile second scanner to be located in the car park. Replace old scanner with new permanent scanner. Run two scanners until a point in time where the waiting list is reduced to effectively zero. Removed temporary scanner and introduce an extended day 8am to 8pm scanning scheduled on the new scanner.	Waiting list is addressed. The extended schedule would allow outpatients to be blocked booked minimising interaction between the cohorts. The extended should address the current increase in demand though waiting list would be expected to accumulate again.

diagram and that the process of creating and validating the RP was a powerful means for staff to reflect on the service they worked in. The final RP considered multiple perspectives and reflected a multitude of perceived problems, service constraints and factors contributing to workload (P Checkland, 1999; Lewis, 1992) (Rcsi, 2011). The SSM approach adopted yielded insights rather than testable results and required the researcher to work with groups when deciding on what to include (Ackermann, 2012b).

The final RP was constructed using the software Microsoft paint and Microsoft publisher which contravenes the predominantly freeform and unstructured nature favored for RP generation(Berg, 2015). As the purpose of the model was to convey a shared understanding and to disseminate to a wider community a more professional finish and clarity was required. The RP however does not purport to describe every CT department's service claiming instead to be a representation of the reality of those interviewed(Bell et al., n.d.; Rodriguez-Ulloa & Paucar-Caceres, 2005). While RPs are usually considered merely a by-product of the process of investigation, as a communication tool the final RP fulfils its purpose of communicating the shared understanding and perspectives of the healthcare staff(P Checkland, 1999; Fougner & Habib, 2008; Lewis, 1992) . This RP is the first of its kind as no other rich picture of a CT service has been found for objective comparison.

Waiting lists have purposefully been described as an external factor as they are not a concern for those directly involved in providing the service on a daily basis. They are an unintended consequence or emergent behavior related to the increase in demand and become a managerial or governance problem over time (Marshall et al., n.d.; Sterman, 1994).

Examples have been provided of four immediate changes which resulted from the RP diagramming process. This reaffirms RP diagramming as a vehicle for action research, changing the problem situation in the very process of researching it (Morrison & Lilford, 2001; Rose, 1997). These changes were not imposed, or even knowable in advance(Bate, 2000). Gaining buy-in for the project was aided by ensuring that important and relevant issues were identified, and that the work resulted in quick tangible changes and benefits to the department(P R Harper & Pitt, 2004).

4.2 Challenges

The full list of perceived issues highlights the challenges facing modern radiology departments and these challenges will not be solved by this study. While we cannot analyze all the issues within the scope of this study, one issue is elaborated on; the staff experience of how the RIS and PACS support workflow. Feedback indicated that the information system did not adequately support the CT workflow. Staff highlighted how RIS information regarding the patient's blood results needed to be verified on a separate laboratory information system and how at the point of scanning a radiographer was required to toggle between two screens to ensure that they had visibility of the clinical history and comments and blood results/prompts. As a workaround some radiographers were found to use a paper schedule to organize the daily list and document the blood results and other considerations such as pregnancy and infection status on said paper schedule, thus evidencing a gap between how the system is used and how it was intended to be used (Unertl, Weinger, Johnson, & Lorenzi, 2009). Radiology staff also listed the non compliance of ward staff regards checking the status of CT scan times on the RIS as an issue which resulted in phone call interruptions and distractions. The ability of the department to scan patients is constrained by the effort required to safely organize inpatient exams and further research is required into the ergonomics of the information system (Unertl et al., 2009).

4.3 Targeted Service Improvement Recommendations

Consensus was reached on three culturally desirable and feasible service improvement recommendations (Table 4). RP diagramming provided a strategic opportunity for meaningful decision-maker involvement allowing a tangible space to discuss and negotiate worthwhile recommendations for change (Bell et al., n.d.). While some argue that SSM is not a decision making tool and rather a post hoc measure to justify the status quo (Bergvall-Kareborn, 2002) it did, in this case study, arrive at a service improvement recommendation (number 3) that had not previously been considered by either facilitator or management staff. Benefits of the inclusion of decision makers in the research project included providing them with an opportunity to internalize research knowledge, promotion of trust and interest in the project, higher likelihood of implementation and a more meaningful focus than it might otherwise have had (Paul Robert Harper & Pitt, 2004; Monks, Robinson, & Kotiadis, 2016; Ross, Lavis, Rodriguez, Woodside, & Denis, 2003).

4.4 Research Limitations and Further Work

In operations research lacunae are gaps where deep fundamental questions remain unanswered (Ormerod, 2014). SSM requires the OR researcher to ask whether the voice of all the affected was included. A limitation of this work is that the voice of the patient and general practitioner (GP) was not included in the process of creating a RP diagram (Ormerod, 2014). While the seniority and experience of participating staff was high, staff were primarily chosen for interview based on their availability. SSM is subjective in nature with the researcher acting as a research tool. In this case the researcher was employed as a CT radiographer in the case study department for over six years, ensuring proximity with staff in both a physical and social sense and minimizing the potential impact of the Hawthorn effect. (McCarney et al., 2007) Future work will focus on the testing of the targeted set of service improvements scenarios in a simulation model of the radiology service.

5 CONCLUSIONS

The creation of a RP provided an opportunity for staff to reflect on the environment they work in and service they provide and resulted in some immediate workflow changes. While the RP may not resonate fully with every CT department's service it provides an effective tool for sharing this department's experience of service provision and is a useful alternative to a text based description of a CT service. As well as identifying specific service improvements the list of perceived issues presents decision makers with multiple areas for improvement. Rich picture diagramming and SSM permit radiographers to consider the "familiar landscape" of a radiology department with "new eyes" (Proust, 1934).

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